Roman impact on the landscape near castellum Fectio, The Netherlands

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Abstract

Castellum Fectio was one of the largest fortifications along the *Limes*, the northern border of the Roman Empire. The castellum, situated 5 km southeast of Utrecht, the Netherlands, was occupied from around the start of our Era to ca AD 260. It was situated along a river bend of the Rhine that was cut off from the main stream during the occupation of the Roman fort. A six m long sediment sequence of the infill of the residual channel was studied. Pieces of Roman wall plaster, glume bases of *Triticum spelta* and radiocarbon dates indicate that the sediment sequence represents the period of Roman occupation. The combined analyses - palynological, macrobotanical, entomological and chemical - allow a detailed reconstruction of changing environmental conditions as a consequence of the Roman occupation.

The pollen record reveals a dramatic decrease in arboreal pollen, suggesting that the Romans were involved in large-scale deforestation, transforming semi-open parkland to a landscape of meadows and agricultural fields. Non-pollen palynomorphs (NPPs), botanical macrofossils and insect remains support this conclusion. The recorded mycoflora shows a shift from the tree pathogen *Kretzschmaria deusta* to fungi associated with herbaceous plants, concurrent with the decrease in arboreal pollen. The presence of masticated bran fragments of cereals, clover remains, eggs of intestinal parasites and entomological and geochemical data indicate that the upper part of the sequence largely reflects the contents of dumped faeces.

Horses may have brought seeds of salt tolerant species in their intestinal tracts to Fectio, which was situated outside the influence of the sea.

Key words: Roman impact, Fectio, palaeoecology, palynology, deforestation, The Netherlands

Introduction

Human impact on natural vegetation has been demonstrated in pollen diagrams since the '40s of the last century (Behre 1981). The impact can be diverse, including deforestation, effects of grazing, crop cultivation and eutrophication. Kalis et al. (2008) presented an overview of past vegetation developments in the upper part of the Rhine delta in the Netherlands and Germany on the basis of several pollen diagrams produced by the research group of D. Teunissen (Radboud University, Nijmegen) with newly calibrated ^{14}C dates. The landscape of this area was dominated by forest before the onset of the Neolithic period, and only minor changes occurred during the Neolithic. At the start of the Bronze Age tree pollen declined, slowly at first, but later more drastically, concurrent with an increase of Poaceae, Ericales, *Rumex acetosella*-type and *Plantago lanceolata*. This signals the establishment of large open areas (meadows, arable land) and the existence of heathlands on poor sandy soils. This development continued into the Iron Age and in the Kleefse Beek record (Teunissen 1990 in: Kalis et al. 2008) the number of arboreal pollen reached a minimum at around 500 BC. In most pollen records, the occupation of the Romans cannot be distinguished from the general trend of deforestation during the Iron Age. The end of the Roman period and the start of the Migration Period can usually be recognized in pollen diagrams as an increase in arboreal pollen percentages. The region was probably predominantly forested again at around AD 500.

A sediment record spanning the Roman period was recovered from an in-filled river channel located near the Roman castellum Fectio (Fig. 1). Fectio was one of the first three military bases built at the start of the 1st century AD, along with castella at Meinerswijk and Velsen (Polak 2009). The fortifications were part of a linear frontier system situated along the Lower Rhine, and were probably intended to create a safe corridor for transport as protection against Germanic invasions (Polak 2009; van Dinter 2013). Eventually, at the end of the 1st century AD, this defence system became the *Limes*, which was the northwest frontier of the Roman Empire (Kooistra 1996; Polak 2009; van Dinter 2013). The site Fectio (52°3'31.62" N, 5°9'37.43" E) was initially built on the southern bank of the Roman Rhine and was probably occupied from shortly before or around the beginning of the Era until the end of the third century AD (Polak and Wynia 1991; Zandstra and Polak 2012).

The objective of the present study is to further assess the impact of the Roman occupation on the vegetation around Fectio and in the Kromme Rijn area. Both the moment of occupation of the site and the abandonment by the Romans could be reflected in the pollen record if the complete Roman period would be covered in the sediment record. The expectation is that the arrival of the Romans would be followed by a decrease of arboreal pollen, as deforestation will have occurred to meet the large demands of wood for timber and fuel. Additionally, we are interested in the record of agricultural practices near the site. Based on the analysis of pollen, non-pollen palynomorphs (NPPs), botanical and entomological macrofossils, archaeological finds, moss remains and geochemical analyses we will provide a detailed reconstruction of the vegetation development and human impact in the region during the Roman period.

Materials and Methods

Previous studies

The earliest camp on the location of castellum Fectio was built on the outer bank of a large Rhine meander. The northern part of the camp defences disappeared after erosion by the river (Polak and Wynia 1991; Zandstra and Polak 2012). Subsequent building phases of the castellum were located further to the south, probably following the retreat of the river bank. When the large meander was cut off from the main channel, the river channel adjacent to the castellum became a nearly 100 m wide residual channel that started to silt up (van Dinter 2013). This process was apparently accelerated by the dumping of waste into the residual channel. Pottery shards dated to the start of the third century AD were found in the upper sediments of the residual channel (Polak and Wynia 1991). This led to the conclusion that the channel was completely filled up during the course of the Roman occupation, perhaps as early as ca AD 200. The discovery of a Roman ship in the residual channel in AD 1893, ca 100 m northeast of our coring site**,** shows that the channel was still navigable in the early part of the 1st century AD (Polak 2006).

All fortifications in the Rhine delta were initially constructed out of timber and earth (van Dinter 2013) and large quantities of wood were required for their construction. At least seven subsequent forts were built at the site during Roman occupation (Zandsta and Polak 2012). The outline and size of castellum Fectio in the 1st and 2nd century is unknown, but it may have covered a surface of ca 4.5 ha. In the 3rd century stone walls were erected and the fort covered ca 2.6 ha. Fectio was the largest castellum in the Netherlands and it probably served as a command centre of the limes segment west of the legionary fortresses at Nijmegen and Xanten. The *vicus* (civilian settlement) was situated both east and west of the castellum (Hessing et al. 1997) and covered ca 10 ha during the 2nd century AD (Kooistra 1996; van Dinter 2013).

Research on the wood of the military constructions along the western limes, e.g., forts in Alphen aan den Rijn and Valkenburg, watchtowers and several sections of the Roman road, showed that the timber was mainly acquired in the region surrounding the forts (Kooistra et al. 2013). It seems likely that the buildings in the *vicus* were also mainly built with local wood. In time, the wood used in military constructions changed. In the early Roman period (AD 40 – 70) the timber consisted of a broad wood spectrum, including *Quercus*, *Fraxinus*, *Ulmus* and *Acer*. From ca AD 70 onwards, the share of *Fraxinus* and *Ulmus* decreased strongly, while the use of *Acer* was completely abandoned. The bulk of the timber consisted of *Alnus* from then on. It is therefore concluded that the higher levees were deforested in the early Roman period and it is assumed that managed alder woodlands were introduced as early as the late first century (Kooistra et al. 2013). Apart from timber for building, wood was also required as fuel.

Earlier research by Kooistra (1996) showed that some crops were cultivated in the Kromme Rijn area, e.g., *Hordeum vulgare* (barley), *Triticum dicoccum* (emmer wheat) and *Linum usitatissimum* (linseed/flax). Cattle were the most common of the domestic animals, but sheep/goat and pig also occurred (Cavallo et al. 2008; Groot 2008; Groot and Kooistra 2009). Some plough marks dated to before AD 200 were found to the west of castellum Fectio, indicating that farmers were active near the site (Kooistra 1996). Horses played an important role in the transport of goods and soldiers between the different castella along the *Limes*.

Fieldwork and lithology (Table 1)

A sediment core was taken on November 10th 2011 from the infill of a residual channel of the Rhine. The core location was situated ca 75 m north of the former castellum wall (youngest phase) and ca 25 m from the southern edge of the former channel (Fig. 1). Approximately 6.7 m of sediment was recovered (core diameter 6 cm). The top 110 cm was discarded as it consisted of reworked material. The following 80 cm (110-190 cm) was cored with a gouge. A piston core was then used to retrieve sediments up to a depth of 673 cm, where an impenetrable sandy layer was reached. Cores were retrieved in 1 m long (or shorter) segments, transferred to plastic tubes, wrapped in plastic foil and stored in a cold room at 4°C until further processing. The lower part of the core (673-535 cm) consisted of clay with several sandy layers. Some coarse detritus layers were present in the sediments below 650 cm. Gyttja was deposited on top of the clay deposit (535-375) and merged into a 30 cm thick clay layer (375 to 345 cm). The gyttja was overlain by a predominantly organic sediment (peaty clay) at ca 345 cm. This organic sediment was intercalated with several clay layers. The sediment from 185 to 110 cm consisted of oxidized sandy clay.

Radiocarbon and archaeological dating

Three levels (196, 300 and 411 cm depth) were selected for AMS ^{14}C dating to estimate the age of the studied sediment interval. Seeds and fruits from terrestrial plants were collected and dated at the Centre for Isotope Physics of the University of Groningen. The radiocarbon dates (in BP) were converted to calendar years using the computer program CALIB Rev 6.0.1 with the IntCal09 ^{14}C calibration curve (Stuiver and Reimer 1993; Reimer et al. 2009) and time intervals are presented as years BC or AD. We sieved the entire sediment core for archaeological material.

Microfossil analysis

Subsamples of ca 0.8 cc each were taken at regular intervals and 31 levels were studied. The samples were prepared according to Faegri and Iversen (1989). *Lycopodium* tablets were added to allow calculation of pollen concentrations (Stockmarr 1971). The material was embedded in glycerol gelatine and sealed in with paraffin wax. Microfossils were counted at a magnification of 400x, or 1000x if necessary. Pollen was identified with the keys and illustrations of Moore et al. (1991) and Beug (2004). Non-pollen palynomorphs (NPPs), such as fungal spores and algae, were identified using Lundqvist (1972), van Geel (1978), van Geel and Aptroot (2006), van Geel et al. (1981, 1989, 2003, 2011) and Vánky (1994). To check for the presence of intestinal parasite eggs (indicators of faeces; Bouchet et al. 2003), three samples (at 235, 245 and 337 cm depth) were processed by W.J. Kuijper (Archaeology and Bio-Archaeology Department of Leiden University). The 10-100 µm fraction was surveyed microscopically.

Microfossil slides were counted to a sum of at least 250 grains of pollen sum taxa (trees, upland herbs). Herbaceous pollen of swamp and aquatic taxa, spores and other NPPs were excluded from that sum. Percentage diagrams and a pollen concentration diagram were produced using the TILIA program (Grimm 1992/2004). Zonation of the pollen diagram is based on visual interpretation of the pollen record (AP/NAP ratios).

Macrofossil analysis

For macrofossil analysis, 1 cm thick samples (each one ca 13 cc) were taken at the same levels as the pollen samples. These samples were immersed in ca 40 ml 5% KOH solution for at least 24 hours and then shortly boiled. Macrofossils were recovered after washing the samples over a 180 µm mesh sieve. Fruits, seeds, other plant remains and zoological remains

were handpicked from the residue using a stereomicroscope and stored in glycerol until identification

Most fruits and seeds were identified using the catalogue of Cappers et al. (2006) and the reference collections of the University of Amsterdam and the Cultural Heritage Agency (RCE, Amersfoort). *Juncus* seeds and Poaceae fruits were identified with the key and illustrations of Körber-Grohne (1964). Pieces of wood found among the macrofossils were identified anatomically. Thin sections were cut by hand with a scientific razor blade from radial, tangential and cross planes and identified with magnifications of 40-400x. The keys and illustrations of Schweingruber (1978) were used. For the identification and ecology of Bryophytes the BLWG Verspreidingsatlas Online, Hennekens et al. (2010), Landwehr (1984), Siebel and During (2006), The Plant List (2012) and Touw and Rubers (1989) were used. Fourteen additional samples (average: 167 cc) were taken from remaining parts of the core for the analysis of arthropod remains. These samples were sieved over a 106 µm mesh sieve, if necessary boiled with some Na_2CO_3. The encountered remains were in a well-identifiable state, still baring a surprisingly large proportion of hairs and scales, and Aphids remains had articulate legs. The arthropod remains were concentrated by means of paraffin floatation (Coope and Osborne 1968). All Coleopterous remains, like (parts of) heads, thoraxes and elytra, were assigned to a taxon in order to allow quantitative analysis. Additionally other beetle parts were used for identification. The results are presented as minimal numbers of individuals. Identification of Arthropod remains was done by means of comparison with the collection of Naturalis Biodiversity Center (comprising the RMNH and ZMA collections) and using Freude et al. (1965-1983) and Lohse and Lucht (1989-1994) as the most important reference for the Coleoptera. The main source of ecological information was Koch (1989-1992). Taxonomy and nomenclature follow Vorst (2010). The identification of Lepidopterous larval head capsules and the use of male genitalia from intact abdoma of *Enicmus* and *Latridius* are worth mentioning. Additional remains of a selection of other Arthropod groups were collected and identified.

Mammal hairs were identified by H. van Haaster (BIAX *Consult*) at 400x magnification, using Appleyard (1978), Brunner and Coman (1974), Deedrick and Koch (2004) and De Marinis and Asprea (2006) and the reference collection of BIAX *Consult*.

PALAEOASSOCIA analysis

The dataset of botanical macrofossils was analysed according to the method described in Schepers et al. (2013a) in order to identify groups of co-occurring taxa. First, an index of association was computed for each combination of taxa in an individual sample with PALAEOASSOCIA, based on present day concurrence values in thousands of Dutch vegetation relevees (for details on this analysis see Schepers et al. 2013). This analysis was performed for each fossil sample. Second, the resulting association matrix for each sample was re-ordered manually so that overlapping groups were constructed containing as many positively associated taxa as possible. This resulted in 2 to 19 groups of taxa in individual samples, sometimes with considerable overlap in species composition within a sample. Third, all 172 groups (each one being a subset of taxa within a sample) of more than ten taxa were analyzed by means of PALAEOASSOCIA, now in order to identify the best fitting plant communities as described in the five parts of the Vegetation of the Netherlands (Schaminée et al. 1995a,b; 1996; 1998; Stortelder et al. 1999). For each group, a threshold value was calculated on the basis of the number of taxa in a group and the weirdness-values of the most likely association (compare Schepers et al. 2013). All suggested plant communities above the threshold value were considered unlikely and skipped. Quite often, groups with considerable overlap in species within one sample were assigned to the same plant community. Finally, the amount of

occurrences of each plant community (below the threshold value) in all 172 subsample groups was calculated at the level of sub-associations and the fourteen most commonly occurring plant communities (more than ten occurrences each) were used to reconstruct both the local vegetation and the likelihood that specific plant communities had derived from a greater distance. The latter was assessed by the absence of contact communities and successional communities as well as the geological and/or geomorphological circumstances under which that plant community nowadays occurs according to the internet database SynBioSys, which is the digital counterpart of Vegetation of the Netherlands (Hennekens et al. 2010). The results are available up to the level of sub-associations, but we have grouped them to the level of associations to avoid over-interpretation.

Faecal biomarker analysis

Sterol faecal biomarkers (5β-stanols and bile acids) were isolated for analysis from layers that were expected to contain faeces (213, 276 and 292 cm depth) following the methods of Bull et al. (1999a). GC/MS analyses were conducted using a ThermoQuest TraceMS instrument equipped with a fused silica capillary column (Chrompack CPSil-5 CB, 50 m x 0.32 mm) coated with a 100% dimethylpolysiloxane stationary phase (film thickness 0.12 mm). The oven temperature was held at 40°C for one minute, following injection, then programmed to 200°C at a rate of 10°C min^{-1} then to 300°C at a rate of 3°C min^{-1} with a final hold-time of 20 min. The ion source was maintained at 200°C and the transfer line at 300°C. The emission current was set to 150 mA and the electron energy to 70 eV. The analyser was set to scan m/z 50-650 with a duty cycle time of 0.6 s. GC/MS peak assignments were made by comparison with known mass spectra.

A discrimination can be made between the faeces of different animal groups using the C_{27}/C_{29} 5β-stanol ratio (Bethell et al. 1994; Evershed and Bethell 1996). As herbivores ingest only plant-derived sitosterol, their excrements contain relatively high amounts of C_{29} 5β-stanols. This ratio can therefore be used to differentiate between omnivores (humans and pigs) and herbivores (horses, cows, etc.).

Results

Lithology (Table 1)

The sand layer below ca 6.7 m depth is interpreted as a channel deposit, forming the base of the residual channel. Initially the water depth in the residual channel was over 5 m deep at the coring site, and less than 4 m when the gyttja started to form. Intercalated clay layers at 375 – 345 cm and around 320 cm depth indicate temporary flooding of the residual channel during peak discharges of the river Rhine. Once the 'peaty' layer started to form, the water depth at the coring site had decreased to less than 2 m and the residual channel turned into a swamp. The top of the 'peaty' layer is oxidized, demonstrating that the residual channel at that time was nearly completely filled and only formed a moist depression in the landscape.

Radiocarbon dating (Table 2) and archaeological evidence

All three AMS radiocarbon dates show overlapping calibrated ages and indicate that our sediment record was formed during the Roman Period. Fragments of Roman wall plaster were found at multiple depths throughout the core (614-148 cm). Some plaster fragments were identified by L. Laken (Radboud University, Nijmegen). The structure of the plaster was

very coarse, and the fragment found at 222 cm displays red and white paint (Fig. 2a). Plaster fragments recovered from the deepest part of the core confirm that the infilling of the residual channel started during the Roman period. In addition there is the evidence of remains of *Triticum spelta*, present at 667 cm depth, indicating the presence of Romans when the deepest sediments of our core were deposited. A ca 4 cm long corroded metal nail was found at 200 cm depth. XRF spectrometry by H. Huisman and B. van Os (Rijksdienst voor het Cultureel Erfgoed, Amersfoort) showed that the corrosion of the nail consists of manganese oxide while sulphides (indicative for contact with salt water) were absent.

Microfossils and zonation of diagrams (Figs. 3 and 4)

Zone I (667-510 cm depth) is characterised by relatively high amounts of arboreal pollen. The tree pollen assemblage is mainly composed of *Alnus* pollen. Other prominent taxa are *Betula*, *Corylus avellana*, *Fagus sylvatica* and *Quercus*. Fern spores are mainly present in this zone. Pollen grains of *Plantago lanceolata* and *P. major/media* were found in Zone I, but these taxa are present throughout the record and do not show major changes. The only non-pollen palynomorphs (NPP) in Zone I that are present in fairly high numbers (ca 5%) are the spores of the parasitic, tree-inhabiting fungus *Kretzschmaria deusta* (van Geel et al. 2013). Some spores of other fungi (e.g. coprophilous Sordariales) are only present in low percentages.

Zone II (510-347 cm depth) can be perceived as a transitional phase between Zones I and III. It encompasses a period showing decreasing numbers of arboreal pollen and a concurrent increase of non-arboreal pollen. The decline in total tree pollen is mainly the result of the decrease of *Alnus*. *Betula* and *Corylus* are also noticeably decreasing, but other arboreal taxa do not yet show such a trend in Zone II. This is shown more clearly in the pollen concentration diagram (Fig. 4). *Fagus sylvatica* and *Quercus* pollen seem to remain at the same level as in Zone I and only start to decrease in the upper part of Zone II. The arboreal taxa are mainly replaced by human impact indicators, such as Poaceae, Fabaceae and cereal pollen. Fabaceae pollen also occurs in clumps of several to many grains (Fig. 5e), indicating deposition of unripe inflorescences at the site (see Discussion). A single observation of *Linum usitatissimum* (flax) pollen was made in this Zone.

In Zone III (347-115 cm depth), the percentages of total arboreal pollen drop below 1%. The percentages of pollen of herbaceous taxa are generally very high, and Fig. 4 shows that the pollen of Poaceae and cerealia show an increase in concentrations as well. Apart from the Poaceae, there are remarkably high numbers of Fabaceae, *Trifolium*-type (Fig. 5d) and *Lotus* pollen. Cereal pollen shows a maximum at 222 cm depth. Large amounts of different fungal spores occur in Zone III, while *Kretzschmaria deusta* disappears from the record. The fungi that are present in Zone III live either on dung or on herbaceous plants. Spores of coprophilous fungi, such as *Sporormiella*-type, *Podospora*-type, *Sordaria*-type and other Sordariales (Lundqvist 1972), are of regular occurrence in Zone III. No eggs of intestinal parasites where recorded during regular microfossil analysis, but W.J. Kuijper (Leiden University) found eggs of the parasites *Trichuris* and *Ascaris* during additional microfossil analyses. Some ubiquitous fungi such as *Chaetomium* and several different Ustilaginales are common in Zone III. *Chaetomium* (Fig. 5i) can occur on dung but also on substrates such as dead plant material (van Geel 1978). Ustilaginales are common on many different species of herbaceous plants (Vánky 1994). The fungal spore record drops suddenly from high values at 193 cm (predominantly organic sediment) to a complete absence at 157 cm (minerogenic sediment).

Three previously unidentified Types (Figs. 5j-n) were encountered during microfossil analysis and where named Type HdV-593, Type HdV-594 and Type HdV-595. The first two Types are fungal spores resembling the genus *Gilmaniella* (W. Gams, pers. comm.; Seifert et

al. 2011). Type HdV-595 is a black cell structure that shows a pitted pattern. It resembles burned wood fragments.

Botanical macrofossils (Figs. 6, 7 and 8)

The taxa encountered during macrofossil analysis were grouped in 11 categories, based on the habitat types of Tamis et al. (2004). The first three habitat types (crops, weeds, and plants of compacted soils) contain taxa that are indicators of human impact. Some of the most notable macrofossils indicative of human impact include the rachis internodes and bran fragments of *Hordeum vulgare* (barley) and *Triticum* spec. (wheat) (Figs. 2f-j). The bran fragments appear to have been masticated. Additionally, high amounts of glume bases of *Triticum spelta* (spelt wheat) were found. Four additional species grouped under "Crops" are *Beta vulgaris* (beet), *Coriandrum sativum* (coriander; Fig. 2k), *Linum usitatissimum* (flax/linseed) and *Papaver somniferum* (opium poppy; Fig. 2l). Several seeds of *Agrostemma githago* (corncockle; Fig. 2q) and one of *Orlaya grandiflora* (large flowered bug parsley; Fig. 2n) were recorded. Other notable botanical macrofossils are the numerous flower fragments of *Trifolium* (clover; Fig. 5a,b).

Unexpectedly, four species of salt-tolerant plants were identified in our record, despite the fact that Fectio was located outside of the tidal reach. *Juncus gerardii* (saltmarsh rush) is very common in our record. The other recorded species that typically occur in marine or brackish environments are *Triglochin maritima* (sea arrowgrass; Fig. 2p), *Aster tripolium* (sea aster) and *Atriplex littoralis*-type (saltbush).

Figure 7 shows the record of leafs, stalks and branches of mosses. Ten moss-species could be identified with certainty, of which five (*Antitrichia curtipendula*, *Leucodon sciuroides*, *Homalia trichomanoides*, *Neckera complanata* and *N. crispa*) grow on trunks and/or branches of living trees, mainly in damp forest with a high air humidity. *Amblystegium serpens* requires wet substrates such as stone or decaying wood (Touw and Rubers 1989). *Drepanocladus aduncus* and *D. polygamus* grow in wet to most conditions. The other recorded taxa were hygrophilous Amblystegiaceae.

The wood remains (Fig. 8) are dominated by *Alnus* (mostly chip-like pieces, also some roots). *Salix* (willow) is mainly represented by small-diameter pieces of roundwood. The occurrence of two fragments of *Abies alba* (silver fir) and one of *Pinus* (pine) is remarkable. *Abies* is not native to the Netherlands, and the closest natural occurrence was in Central Germany, far upstream of the Rhine. Charcoal is present in several samples, and the charcoal assemblage is again dominated by *Alnus*. Charcoal of *Salix, Quercus* and *Ulmus* was found as well. Bark fragments could not be identified anatomically, but most of these likely belong to *Alnus* too.

Zoological macrofossils (Electronic Supplementary Material 1 and 2)

A wide variety of arachnid and insect taxa were recorded, including aphids (Fig. 9a), spiders (Fig. 9b), pseudoscorpions, fly puparia, caterpillars, bugs, ants and beetles. The total number of recorded taxa is 104. The number of taxa belonging to the Coleoptera, the group that was sorted out systematically, is 93. Some of the encountered taxa are strong indicators for natural environmental conditions, while others can be used to reconstruct Roman economy, local activities and depositional processes.

A relatively small number of water insects was found. Some of them (e.g. Elmids; Fig. 9c and 9d; ESM-1) are indicators for clean flowing water and are only found in the lower part of the sequence (652 and 619 cm depth). Waterside beetles were found in a large part of the sequence. At least eight of the encountered species are halotolerant and can, for instance, be

found on salt marches: five of the fytophagous beetles, *Phaedon cochleariae*, *Plagiodera versicolora*, *Phyllotreta nemorum*, *Chaetocnema hortensis* and *Oxystoma cerdo*, one of the water beetles, the eurytopic *Hygrotus impressopunctatus* and two of the waterside beetles *Cercyon bifenestratus* and *C. tristis.* These species also occur on inland sites. Halobiontic and halophilous species were not found.

Many of the insects are anthropophilous, in the sense that their abundance is higher in human settlements than in nature. Fytophagous beetles such as *Chaetocnema hortensis* can be a pest in cereal production and *Phyllotreta nemorum* in the culture of cabbage. The recovered fly puparia mostly belong to groups that live in dung, like Sepsidae and Sphaeroceridae. Several species of *Aphodius* were found and most of them can live in isolated patches of dung. Cryptophagids and Latridiids are fungus feeders. The most frequent species *Latridius minutus* and *Enicmus histrio* as well as *Monotoma spinicollis* and *M. picipes* are predominantly found in mouldy hay and straw as well as in manure. Within this indoor habitat, the blind *Aglenus brunneus* and *Xylodromus concinna* live in dark corners and burrows. The Histerids *Acritus nigricornis* and *Atholus bimaculatus* are frequently found in manure heaps.

Thermophilous species like *Musca domestica* thrive in high quantities of manure that are heating. Remarkable finds are the ant *Hypoponera punctatissima,* both a female and a worker, *Cercyon nigriceps* (=*C. atricapillus*) and *Aphodius lividus.* This ant is a rare species that makes nests in heating plant remains. *C. nigriceps* was common in anthropogenic, heating heaps of plant remains only recorded during the first half of the 20th century in the Netherlands. *A. lividus* is a Mediterranean species with temporary populations in other parts of Europe in horse and cow dung, with a single find in the Netherlands more than a century ago. It disappeared from England and most of Germany and France during the second half of the 20th century.

A surprisingly large variety of stored-product insects was found throughout the sequence (Figs. 9g-i). The most important and also most informative is *Sitophilus granarius* (the grain weevil), which reproduces only on concentrations of stored cereals. The fragmentation of these remains is relatively heavy. For the implications of this fragmentation see the Discussion.

Some species that are associated with wood were found as well. *Anobium punctatum* and *Ptilinus pectinicornis* are dominant in the samples. Unlike the majority of wood boring beetles, *A. punctatum* lives almost exclusively in dried and worked wood of all kinds, mostly indoors. *P. pectinicornus* can also be found indoors, mostly occurring in hardwood. None of a multitude of species that exclusively live inside the wood and bark of standing trees, dead or alive, was found. One species that was encountered lives in rotten wood (*Valgus hemipterus)*. *Plagiodera versicolora* lives on *Salix* leaves. *Orchestes quercus* lives on the leaves of oak, preferably of small trees. It was found in the lowest part of the sequence. The most strongly anthropophilic species is *Pediculus humanus* (Fig. 9m). It is impossible to identify single specimens to the level of head- or body louse.

The sediment contained several other types of faunal remains, of which three are depicted in ESM-2. Ephippia of the cladocerans *Simocephalus*, *Moina* and *Daphnia* were distinguished, occurring at several levels throughout the core. Statoblasts of Bryozoa are present throughout the record, but show a peak in Zone II. Ostracods are mainly present in Zones II and III.

Some darkbrown tough crusts were found at 608 and at 268 cm depth. These crusts do not only contain plant remains, they also contained mammal hairs (horse and human hairs; Figs. 2b-d). The crust material was analysed with X-Ray Fluorescence Spectrometry (XRF) by N. Walraven and B. van Os and appeared to contain mainly mineralized calciumphosphate with plant remains.

PALAEOASSOCIA *analysis*

The association most frequently identified by PALAEOASSOCIA was the Chenopodietum rubri association. This pioneer plant community grows on moist places rich in nitrogen (Schaminée et al. 1998). The grassland association Ranunculo-Alopecuretum geniculati is the second-most important association, occurring 58 times. It is characteristic of soils that are inundated outside of the growing season for long periods. It is encountered on sandy as well as on clayey soils, usually grazed by cattle or horses (Schaminée et al. 1996). This vegetation can form mosaics with associations within the Bidentetea tripartitae alliance, to which the Chenopodietum rubri belongs. The two associations that occur most commonly in the Fectio record therefore nowadays often occur next to each other.

The third association in terms of its importance is the Ranunculo–Senecionetum aquatici association (40 occurrences). This grassland association occurs in meadows and pastures in the valleys of rivers and brooks, on base-rich soils that are, however, poor in calcium (Schaminée et al. 1996). This vegetation type can transgrade into the alliance Lolio–Potentillion, which includes the Ranunculo–Alopecuretum geniculati.

Another important association (36x) is the Artemisio–Salicetum albae association, a riparian forest type, occurring exclusively near rivers (Stortelder et al. 1999). The alliance Lolio–Potentillion is an important contact vegetation again, as is the Bidention tripartitae, in which the fifth important association, the Polygono–Bidentetum (33x) as well as the aforementioned Chenopodietum rubri are included. Similarly important, with 33 occurrences, is the association Echio–Melilotetum. In the river area, this pioneer association is in contact again with associations within the Lolio–Potentillion alliance. The association Erigeronto–Lactucetum (27x) is another pioneer vegetation along (larger) rivers, which is strongly promoted by human disturbance. This vegetation forms zones together with the most common association of our Fectio record, the Chenopodietum rubri (Schaminée et al. 1998).

Next in importance, with 25 occurrences, is the association Centaurio–Saginetum. This is a coastal pioneer community of sandy soils, in which the halophytes *Triglochin maritima*, *Aster tripolium* and *Juncus gerardii* occur in respectively 9, 15 and 32 percent of all relevées (Hennekens et al. 2010; Schaminée et al. 1998). This association can, under very specific conditions in recently developed dune slacks, follow the Chenopodietum rubri, but such a biotope was non-existent in the vicinity of Fectio. There are no other plant communities identified in the Fectio record that normally occur next to, or on succession of the Centaurio-Saginetum. Furthermore, it is the only identified plant community absent in the present day Dutch inland river area and the only one explicitly coast bound (Weeda et al. 2003). The PALAEOASSOCIA method has also been applied to regions in the Northern Netherlands (Schepers et al., 2013b) where halophytes are occurred naturally. There, it proved indeed possible to identify an continuous natural transition from salt marsh communities to profoundly disturbed synanthropic communities higher up the fresher part of the marsh.

In summary, all plant communities identified are presently found in relation to one another in the river area, either through zonation or succession, with exception of the coast-bound Centaurio-Saginetum, which holds most of the halophyte species present in the Fectio macrofossil record. The ‘alien’ character of these species is confirmed by the fact that in the association matrices containing these species it proved impossible to construct an ongoing gradual transfer of overlapping subgroups. This problem would not occur in a dataset of species originating from ecologically related plant communities.

Faecal biomarkers

Fig. 10 shows a partial gas chromatogram derived from the GC/MS analysis of the sterol fraction isolated from the peaty sediment at 213 cm. All three sediment samples contain strikingly similar relative distributions of sterols, the dominant components comprising 24-ethyl-5β-cholest-5-en-3β-ol (5β-stigmastanol), 24-methyl-5α-cholest-5-en-3β-ol (5α-campestanol), 24-ethyl-5α-cholest-5-en-3β-ol (epi-5β-stigmastanol), 24-ethyl-5α-cholest-5-en-3β-ol (5α-stigmastanol). 5β-cholestan-3β-ol (coprostanol), 5β-cholestan-3α-ol (epicoprostanol), cholest-5-en-3β-ol (cholesterol), 5α-cholestan-3β-ol (5α-cholestanol), 24-methyl-5β-cholestan-3β-ol (5β-campestanol) and 24-ethylcholest-5-en-3β-ol (sitosterol) are present, albeit at relatively lower concentrations. The ratio [(coprostanol + epicoprostanol):(coprostanol + epicoprostanol + 5α-cholestanol)] has previously been established as a proxy for inputs of faecal origin to soils and sediments where values of greater than 0.7 are indicative of faecal material (Simpson et al. 1998; Bull et al. 1999a,b,c). Application of this proxy to the GC/MS results, based on peak areas of extracted mass chromatograms of the *m/z* 215 ion, returns values of 0.49, 0.46 and 0.48 for the sediments at 213, 276 and 292 cm depth, respectively. Given the lower relative abundance of the *m/z* 215 ion for coprostanol, *cf*. 5α-cholestanol, these values are lower than had the biomarkers been more concentrated and thereby analysable by GC-FID. These values may therefore be tentatively interpreted as deriving from a mixture of faecal material and, based on the predominance of C_{29} homologues, most likely vegetation; a more secure interpretation would require parallel analysis of an appropriate control. Calculation of the C_{27}/C_{29} 5β-stanol ratio returns values of 0.03, 0.08 and 0.09 for the sediments at 213, 276 and 292, respectively. This indicates that any faecal material present in the sediment will have a predominantly herbivorous origin, i.e. cattle, sheep, horse, rather than omnivorous, i.e. human, pig. Analyses of bile acids - also faeces indicators - were not conducted since the results obtained from the sterol analyses are conclusive. Overall, these results indicate the deposition of vegetative waste mixed, to some degree, with excreta of a herbivorous origin (Bull et al. 2002).

Discussion

Chronological constraints and sedimentation rates

The calibrated age estimates of the three radiocarbon dates all cover a narrow time window around the first two centuries AD. Roman plaster found at 614 cm depth and the presence of *Triticum spelta* at 667 cm depth constrain the onset of sedimentation at our site to the period after 4 AD, when the Romans arrived in the area (Zandstra and Polak 2012).

The age estimate for the uppermost radiocarbon date (AD 70 - AD 129) indicates that the sediment between 614 and 196 cm depth was deposited in a maximum time window of 125 years (AD 4 - AD 129), suggesting very high sedimentation rates. Other archaeological records (Polak and Wynia 1991) also suggest that the riverbed had completely silted up by AD 200, during the period of Roman occupation. Finally, the age estimate at 300 cm (1 BC - AD 70) suggest that the deforestation prior to Zone III was extremely rapid and took place in a period with a maximum duration of 168 years.

Sedimentology and changes in the aquatic ecosystem

The remarkably high accumulation rate of the sediment encourages a closer look at the formation of the sediment body. After the meander was cut off from the main channel, ca 1.3 m of clayey sediment was deposited at the bottom of the channel. The deposition of clays probably resulted from the former channel functioning as a sediment trap during periods of relatively high water levels in the river Rhine, where clay was allowed to settle during

stagnant water conditions. Sandy layers intercalated in the clay were probably deposited during temporary flooding of the residual channel. As the sediment influx reduced, gyttja started to form in the channel. The laminations within the gyttja thin towards the top (ca 540-380 cm) and subsequently 'peaty' clay was deposited (ca 345-185 cm). The deposition of the clays coincides with the onset of Zone III. The top of the 'peaty' layer is oxidized, indicating that the water level in the residual channel temporarily dropped to this depth. Flooding of the residual channel also occurred during the phase in which peaty clay was deposited, as attested by some intercalated clay layers. Therefore, the high accumulation rates may partially have been caused by temporary flooding of the residual channel. However, even accounting for the effects of the deposition of flood-deposits, the sedimentation rate still seems to be high, and other factors will have played an additional role. The 'peaty' layer between 345-185 cm depth appeared to have considerable non-natural (waste) components.

At about 185 cm depth, the organic content of the deposit suddenly decreased. The sediment above this level consists of oxidized sandy clay (orange staining). The microfossil record shows a sudden change here as well; the number of fungal spores suddenly drops from high values at 193 cm to a complete absence at 157 cm, apparently linked with local environmental change. As the residual channel at that time only formed a damp depression in the landscape, this layer is probably part of a deliberate, rapid filling with sediment and human waste in order to raise and threngthen the surface. As pottery dated to the start of the third century AD was found in the overlying layer (Polak and Wynia 1991), it seems likely that this flooding dumping at the end of the second or at the beginning of the third century AD.

The number of recorded water beetles and water bugs is very low, and the occurrences are limited to the lower part of the core (i.e. below 380 cm). The number of hygrophilous beetles is also low, but unlike the water insects they are not limited to the lower parts of the core. Three of the six recorded water beetles species are Elmids. They have a specific ecological preference as they are only found in clean running water. One of the species, *Macronychus quadrituberculatus*, lives on floating wood in rapids in rivers. It was never collected alive in the Netherlands. It was also encountered in the other sediment sequence in the river area that was sampled for insect remains, i.e. the mesolithic site Polderweg-Giessendam (Hakbijl 2001). The combined evidence suggests that *M. quadrituberculatus* was not rare in prehistoric times. *Esolus pygmaeus* and *Limnius muelleri* were only found once, respectively twice in the Netherlands, in single specimens, both in early 20th century (Drost et al. 1992). This means that the ecosystem of the Rhine has changed dramatically. The stenotopic Elmids were not recorded above 619 cm depth. This reflects the local transition from a clean running river system to stagnant water in the residual channel. Above this level we only find a few water beetles indicative of slow-flowing or stagnant water. Swimming water insects are absent from the record above 380 cm and only waterside beetles remains are encountered here. The recorded taxa live either in shallow water or in/on wet ground. This transition reflects the ongoing gradual infilling of the residual channel and the onset of the formation of the peaty clay.

Dumping of waste and dung

An earlier study by Polak and Wynia (1991) already suggested that waste from the castellum and surrounding *vicus* was dumped in the residual channel. This is confirmed by our finds in the predominantly organic layer of the core (345-185 cm) which was originally characterized as 'peaty' clay. Körber-Grohne (1991) points out that much care is required to be able to distinguish fossil dung from peat.

As mentioned before, the non-arboreal pollen taxa show unusually high percentages in this part of the record. Most fruits and seeds (which may partly have been imported with the spelt wheat from distant loess soils) were found in this part of the core as well. The high amounts of glume bases from spelt, for example, suggest nearby processing of wheat. This could also explain the high amounts of cereal pollen grains. The 'peaty' component appears to contain a considerable amount of masticated plant remains (Fig. 2e). Most of those plant remains were 0.2-0.9 cm long monocot stem and leaf fragments, which is an additional indication for a faeces component to the peaty deposit. Other remains that may have passed digestive tracts are masticated bran fragments of barley (*Hordeum*) and wheat (*Triticum*), highly damaged seeds of corncockle (*Agrostemma githago*), and broken sclerites of grain pests. A herbivorous origin of the dumped faeces explains the large amounts of remains of flowers and pollen of *Trifolium* and *Lotus*.

Other evidence for the presence of faecal matter in our sediment record is provided by the geochemical data. The results indicate that the sediment indeed contains faecal biomarkers and is mainly composed of faeces of herbivores (as opposed to omnivores). Spores of coprophilous fungi that normally can be used as indicators for the presence of faeces (van Geel et al. 2003) show relatively low percentages. This can easily be explained by fast dumping (before sporulation of dung fungi) of the faeces in anoxic conditions - viz. in water, where coprophilous fungi cannot grow and reproduce. Strong additional indicators of the presence of faeces are the eggs of *Trichuris* (whipworm) and *Ascaris* (roundworm) (e.g. Kuijper and Turner 1992; Bouchet et al. 2003). Both are intestinal parasites that live in the gut of mammals (Florenzano et al. 2012). A variety of dung fly puparia and dung insects complete the overwhelming evidence that dung forms a main constituent of the organic material, particularly of herbivore origin.

The entomological record contains a multitude of anthropophilous beetles that can be found in abundance in hay and litter, particularly in stables, barns, etc. Other encountered beetles are often found in manure. The most likely nature of the material is stable manure. The presence of indoor wood boring beetles is an indication that the stables were actually constructed of wood, which has been demonstrated for other sites as well (Esser et al. 2010). Another indicative group of insects are the anthropophilous and thermophilous fly puparia, ants and beetles, of which three are now rare, or became locally extinct in the course of the 20th century. These species are indications of heating by microbial activity, which occurs when sufficiently large quantities of decaying matter are accumulated, like in a manure heap.

In order to get an impression of the contribution of dumped refuse and its containing biota, all indoor beetles, dung and manure inhabitants, mould feeders and grain pests were added up. The sequence was divided into an arbitrary number of six zones with minimal differences in total number of insects (minimal numbers of individuals) per zone. The percent-abundance of anthropophilous beetles ranged from 37% in the lowermost zone (667 - 460 cm), to 92% in the zone from 271-195 cm. These estimates are still conservative; if we allocate some Staphylinid genera frequenting decomposing matter in the latter zone to the group indicative of dumped refuse, only one species of 39 species remains that is not included in said group. This species, *Agonum emarginatum*, is a waterside beetle and may even have been attracted to the refuse after it was dumped. This illustrates how dominant the process of dumping waste was in large parts of the sequence.

The presence of horse hairs (fig. 2c) in the calciumphosphate precipitates is an indication that the producers of the dung were horses. Therefore, the most likely nature of a large part of the material is a dump from horse stable manure. These findings fit well with archaeological evidence for Roman cavalry along the limes in the Netherlands. Knowing the origin of much of the organic matter we can re-evaluate the presence and absence of some remains. If cavalry horses were the producers of the manure that is encountered in our core, we expect to

find the remains of fodder as well. Even though idle horses can find their own food through grazing and browsing, working cavalry horses will need extra fodder, compensating for the time they can not graze and for the energy they spend. Traditionally, concentrate fodder is given in those cases. Roman authors mention barley (and oats) grown especially as horse feed (Groot 2008).

What we encountered in our records are mostly the remains of barley and spelt wheat and of grain pest insects. The remains of these pests are more broken than the other beetle remains, which indicates some grinding action, but we cannot discriminate between milled grain beetles ending up in bread and eaten by Romans, and beetles chewed on and eaten by horses. Recovered cereal remains include pollen, masticated bran and glume bases. Also the fragmented seeds of *Agrostemma githago* can be added. One process is enough for explaining these remains, i.e. feeding of cereals in a more or less rough form to horses.

Working horses also need high quality feed such as clovers and other Fabaceae. Remains of these plants are encountered in the pollen record and as inflorescences, and their presence is also reflected by the finds of Apioninae (oligophagous weevils) such as *Oxystoma cerdo*, which feeds on *Vicia*. The fragments of inflorescences and (over-represented) pollen may have been grazed at sites where these plants were dominant and arrived at the coring site as components of faeces of herbivorous domesticated animals, or alternatively they were brought to the horses as fodder. Other plant remains and insects, such as Aphids, could have been introduced in the same way. Beet or flax seed could also have been part of the horse food, as remains of these plants were also found.

The suggested presence of horse dung in the record does not rule out the presence of household refuse or human excrements. However, some elements of that are commonly encountered in household refuse are missing from our record, such as small bones, fish scales, beans, and Bruchids. Only one indicator for dry animal remains is found (*Omosita colon*) in the lowest part of the sequence. However, this species can also occur in plant remains. If there is any household refuse present in our record it is probably a minor component compared to the large amount of stable manure in large parts of the sequence.

Deforestation and wood requirements during the Roman period

The arrival of Romans in an area can generally not be identified in palynological records, as a sudden shift in pollen composition is often lacking (Dumayne and Barber 1994; Kalis et al. 2008). This is also the case in the present study. The arrival of the Romans is most likely not even represented in our record as the Romans probably built their first castellum along an active river channel located further north. Furthermore, macrofossils of *Triticum spelta* (667 cm depth) and Roman wall plaster found from 614 cm depth on, indicate that sedimentation in the residual channel might have even started after the arrival of the Romans in the area. Pieces of plaster found in the core indicate that parts of the fort were already plastered during the 1st century AD. Coarse plaster, such as found here, was popular in the second half of the second century AD, but in this case the coarse structure might indicate that the plastering was done by non-specialists, e.g. Roman soldiers (L. Laken, pers. comm.).

Pollen Zone I displays an open parkland landscape, which was already impacted by human presence, probably caused by native inhabitants in the area (Kalis et al. 2008; Kooistra 1996; Vos 2009). Roman occupation near the sampling site - before the start of the sedimentation at our coring site – may also have played a role. The pollen record (Figs 3 and 4) clearly shows large-scale deforestation of the area around Fectio, probably occurring in less than seven decades during Zone II. The semi-open parkland that was present during Zone I rapidly changed into a landscape where trees became rare. All arboreal species were

affected, although beech and oak started to decrease later than the other tree species. The landscape became dominated by meadows and agricultural fields after deforestation. Non-pollen palynomorphs (NPPs), especially the mycoflora, show a clear link with the vegetation development as reflected by the pollen record. *Kretzschmaria deusta* disappeared synchronously with its host trees, while spores of coprophilous fungi and some other fungal spore types that are often associated with human presence (e.g. *Chaetomium*) became common. The three new types (Type HdV-593, Type HdV-594 and Type HdV-595) broadly follow the same trend as *Chaetomium* and the coprophilous Sordariales. These types can therefore preliminary be characterised as human impact indicators.

Total tree pollen diminished to less than 1% in Zone III. This is much lower than the values found in other studies where *Alnus* and *Salix* usually dominate the arboreal pollen spectra (van Haaster 2003, 2007, 2010; van der Linden 2011; Kalis et al. 2008; Teunissen 1988). High numbers of trees must have been cut down in order to result in such a low value of AP, but non-arboreal pollen may be overrepresented in the record because of the unusual nature of the 'peaty' deposition in the river branch (dumping of waste and faeces of herbivores). Furthermore, the absence of tree pollen does not necessarily point to a treeless landscape because trees that were too young to produce pollen might have grown in the area and evidence from other archaeobotanical research suggests that young alder trees were widely utilized as timber by the Romans (van Dinter et al. in press). Managed woodlands may have occurred in the surroundings of the castellum from the end of the first century onwards as coppiced woods, with alder trees not ageing beyond five to six years (van Dinter et al. in press). The results of the wood analysis also indicate that alder was commonly present, in many cases as chips left after the processing of wood for building purposes. Consistent with the conclusion that the residual channel silted up during Roman occupation, no forest regeneration is detected, indicating that the Migration Period (compare Teunissen 1988; Dumayne and Barber 1994; Kalis et al. 2008) is not represented in the Fectio core.

The forest clearance around castellum Fectio was probably mainly related to wood requirements of the Roman inhabitants. Huge amounts of timber were necessary for building forts such as castellum Fectio and nearby forts in Utrecht and De Meern (van Dinter et al. 2013). Not only did castellum Fectio have at least three building phases (Polak and Wynia 1991; Zandstra and Polak 2012), it was also surrounded by a large *vicus* (Kooistra 1996; van Dinter et al. in press), where timber was also needed for building houses. The demand for wood was not only covered by local wood supply. Pieces of *Abies* wood show that a small part of the wood supply, for example wine barrels, came from far upstream of the Rhine, from Germany at the nearest (Behre, 1969).

There is actual evidence from the core for the use of wood as building material and subsequent degrading. Recovered wood-boring beetles reflect the use of wood in indoor constructions. These beetles appear later in the sequence, from 340 to 179 cm, possibly only when the built structures became older. There is no insect-based evidence for the local presence of full-grown trees other than *Salix*.

The pollen record shows that all tree species were affected in the deforestation, even though not all species were suitable for building. As there was also a strong demand for wood used as fuel, for instance for domestic use, craft activities and cremations (van Dinter et al. in press), tree species not suitable for construction might have been exploited as well. Another important reason for large-scale deforestation was probably to provide space. Space was needed for the buildings associated with the castellum as well as the *vicus*, but possibly also for agricultural purposes. This includes pastures for horses, as the fort was partially manned with cavalry (Zandstra and Polak 2012). Moreover, removing trees was a strategic measure for a castellum on the border of the Roman Empire (Teunissen et al. 1987; Dumayne and Barber 1994). Large areas along the *limes* were cleared of forest to ensure enhanced sight.

Crop plants

Macrofossils of two cereal species were encountered in the Fectio core, i.e., *Triticum spelta* (spelt wheat) and *Hordeum vulgare* (barley). These species were also recorded by Kuijper and Turner (1992) in their study on the diet of a Roman centurion stationed at the castellum in Alphen aan den Rijn, located ca 40 km east of Fectio. *Vicia faba* (broad bean) was encountered by Kuijper and Turner (1992) but is missing from our record. The absence of Bruchid (bean weevil) remains, often better indicators for beans than the seeds of the plants themselves, confirms the absence of *Vicia faba.* Other "missing" food species, as compared to the Roman site at Alphen aan den Rijn, are *Triticum dicoccon* (emmer wheat)*, Anethum graveolens* (dill), *Olea europaea* (olive), *Ficus carica* (figs), *Vitis vinifera* (grapes) and *Pyrus communis* (pear). Kuijper and Turner (1992) suggest that there were no major differences between the castella with respect to food availability. The sample size used in the present study was much smaller (ca 13 cc per sample, while Kuijper and Turner used 500 cc samples). Food species that Fectio has in common with Alphen aan den Rijn (Kuijper and Turner 1992) are *Papaver somniferum* (opium poppy), *Coriandrum sativum* (coriander) and *Apium graveolens* (celery). The seeds of opium poppy were processed as a condiment in food, mostly bread (Pickersgill 2005), but the Romans also knew medicinal and narcotic properties of *Papaver*. The fruits of coriander and celery were used as seasoning. According to Pickersgill (2005) coriander was cultivated in the Mediterranean area and was probably imported into northwest Europe by the Romans. Celery was cultivated by the Romans as well, but could also have grown as a wild species (Kuijper and Turner 1992). It may occur in brackish environments and therefore it is included in the marine habitat type in figure 6 and not among the crop plants. *Beta vulgaris* (beet) and *Linum usitatissimum* (flax/linseed) were found, but were absent in the latrine of Alphen aan den Rijn.

Earlier research in the Rhine delta region suggests that spelt wheat (*Triticum spelta*) was imported (Kooistra 2009). The presence of one fruit of *Orlaya grandiflora***,** a crop weed of rich loess soils, situated at 100 km to the south at the nearest, also points to import of a demanding crop like spelt wheat (see also Pals and Hakbijl 1992). Spelt wheat was probably transported unprocessed, the seeds still in their chaff, as many glume bases and other fragments were found in our core. The grain was likely threshed and winnowed by the soldiers themselves in mealwise portions. This may also account for the high amounts of cereal pollen in Zone III. *Triticum* and *Hordeum* are known to disperse their pollen poorly. They are autogamous and therefore most pollen grains stay in the hulls. The pollen could have dispersed after threshing and subsequently be deposited along with the chaff (Behre 1981, Diot 1982). Cereal pollen may also have been a component of human faeces (from digested bread or porridge) deposited in the residual channel where our core was taken. Cereals, including pollen grains, may also have been given as food for cavalry horses.

Weed seeds were not removed from the wheat before transport, as indicated by the presence of e.g. the large seeds of *Agrostemma githago* (corncockle) and *Orlaya grandiflora*. Corncockle was probably introduced into North-West Europe by the Romans, because the first finds of its seeds were dated to the first century AD and these were all found in Roman context (Bakels 2010). Although all parts of corncockle are poisonous to humans (Frohne and Pfänder 2005), the seeds are commonly found in deposits from Roman settlements (Pals and Hakbijl 1992) and even in faeces (Kuijper and Turner 1992). This indicates that the Romans were not aware of the plant's poisonous effects. In fact, the first accounts of people describing corncockle as poisonous date to the Middle Ages (Frohne and Pfänder 2005).

A variety of grain pests were present throughout the sequence, from almost the oldest to the youngest subsample that contained insect remains (648-179 cm). *Sitophilus granarius*

(grain weevil) is a primary pest on cereals. *Oryzaephilus surinamensis* (saw-toothed grain beetle) thrives on processed cereals whereas *Cryptolestes ferrugineus* (a flat grain beetle) is a common grain pest in temperate climates. *Palorus ratzeburgii* (a small-eyed flour beetle) can be present on grain that is infested by grain weevils. This is an indication that the infestation is an older one and that the cereals were stored for some time, either at the granaries of Fectio (Polak and Wynia 1991) or before arrival at Fectio. Larvae of *Pyralis farinalis* (meal moth) reproduce only on grain with a raised moisture content and in modern times it is only found in spoiled remnants of grain. *Typhaea stercorea* (hairy fungus beetle) is often found on mouldy stored products, but can also be found on other mouldy material.

Ptinus fur/pusillus and *Ptinus clavipes* forma *mobilis* (all spider beetles) can be found on grain in a bad state but can also be found in other indoor locations, feeding on a variety of products. Infestations with grain pests, particularly the non-flying *S. granarius*, are problematic and almost unavoidable in large-scale continuous storage facilities like those of the Roman army. They can have a devastating effect on food quality and quantity. The first five beetle species discussed here are also found together in other grain stores, such as the Roman grain cargo ship studied by Pals and Hakbijl (1992). Their study suggests that coriander may have been used as a pesticide against wheat weevils.

Most of the sclerites of the grain pests were broken, particularly those of *S. granarius.* They are more heavily fragmented than those of beetles that are not associated with cereals, despite the robust sclerites of this species, which do not break easily. Therefore, it is likely that the beetles were ground in some way or another, together with the cereal grains (and weed seeds). The grain was either milled or heavily chewed on. Other studies also concluded that beetles were consumed together with infested food (Kuijper and Turner 1992; Osborne 1983).

Origin of salt-tolerant plant species

One of the most common taxa in our macrofossil diagram is the salt-tolerant *Juncus gerardii*. There are three additional species that are indicative of salt or brackish water conditions (Tamis et al. 2004). These are the seeds and fruits of sea arrowgrass (*Triglochin maritima*), sea aster (*Aster tripolium*) and saltbush (*Atriplex littoralis*-type). The presence of seeds of salt-tolerant plant species in the sediments near the castellum is remarkable, as direct marine influence in the area can be excluded. In fact, marine influence from the estuary in question did not reach far beyond the present city of Leiden (the castellum of Matilo) in Roman times (van Dinter 2013), which is about 50 km to the west of Fectio.

During the construction of the PALAEOASSOCIA association matrices it became evident that no natural transgression of vegetation types containing salt-tolerant species into other syntaxa could be established. The main plant community identified for the subgroups containing the salt-tolerant species, viz., the coast-bound Centaurio-Saginetum, could not be related to the other plant communities. The macroremains of these salt-tolerant species must therefore be of coastal origin.

Three of the four salt-tolerant species occur in the core in low numbers, but many seeds of salt marsh rush (*Juncus gerardii*) were recorded. It seems unlikely that such a high amount of seeds arrived at the site from distant growth locations by regular, natural dispersal mechanisms. However, if encountered in archaeobotanical research, seeds of *J. gerardii* can occur in much higher concentrations than established at Fectio, and therefore van Zeist (1974) excluded this species from the ‘seed sum’. Cosyns et al. (2005) show that especially *Juncus* seeds are effectively dispersed through endozoochory. Wells and Lauenroth (2007) emphasize that a suitable environment is a prerequisite for the invasion of local plant communities by

species from greater distance. Bakker et al. (2007) found that on a relatively short distance, significant differences in the environment obstruct the germination of non-local species, even when their diaspores are disposed through animal dung in high numbers. *Juncus gerardii* is not an obligatory halophyte and may grow at open and/or disturbed locations (Weeda et al. 2003). Around Fectio, but also along the Roman roads connecting fortifications towards the North Sea, the vegetation will have been highly impacted by human presence, including the effects of horses, and salt marsh rush may have been able to germinate occasionally without saline conditions, in the absence of strong competitors. This also goes for *Aster tripolium*. Nonetheless, the slowly growing, short *Juncus gerardii* will not have been able to compete with the local plants in the long run.

A map with the sample frequency of halophytes versus glycophytes (compare Behre 1979 and Brinkkemper 1993, the same species were used here) is shown in Fig. 11. There is a clear trend of decreasing abundances of halophytes toward inland sites, both for military sites and for native settlements. Our Fectio record does not agree with this trend as it has a much higher halophyte percentage. This once again confirms the likely reflection of transport of seeds of salt plants to Fectio. Presence of Roman cavalry is shown for Valkenburg (Glasbergen and Groenman-van Waateringe 1974) and Utrecht (Chorus in press) the 1st century AD, and for other military sites in the coastal zone (Waasdorp et al. 2012) for the 2nd century AD. This could suggest that grazing horses played a role as vectors bringing the seeds of salt tolerant species in their intestinal tracts to areas outside the influence of the sea. We cannot exclude the possibility that farmers have let their cattle graze at sites where salt tolerant plants occurred. This could mean that cattle were moved over large distances (van Geel et al. 2003), after which the faeces, including seeds of halophytes, were deposited near the castellum. However, the occurrence of horsehairs in our record makes the first explanation most likely.

It is not likely that the saltmarsh plants grew locally, as other typical species of such habitats (e.g. *Armeria maritima* and *Glaux maritima*; Tamis et al. 2004; Weeda et al. 2003) that commonly occur in seed assemblages of coastal sites, are conspicuously absent. Moreover, the vegetation types attested by PALAEOASSOCIA also suggested that the coastal vegetation type has no successional or zonal connection to the other vegetation types as identified for the seed assemblages of Fectio. No beetles were found that indicate a brackish environment, contrary to entomoarchaeological studies in the more western part of the Netherlands. In conclusion, the presence of halophytes is most likely linked to the cavalry presence and endozoochorous transport by horses.

Conclusions

A 6 m long sediment sequence was recovered from a residual channel infill located next to Roman castellum Fectio. Using radiocarbon dating and the identification of archaeological remains, the sediments in the residual channel could be dated to part of the Roman Period, i.e. most likely between 4 - 129 AD. The vegetation around Fectio was strongly impacted by the Roman occupation of the area. Human impact is reflected in the pollen record as a dramatic decrease in arboreal pollen from ca 60% to <1%, signalling large-scale deforestation. The landscape was transformed from semi-open parkland to an open vegetation of meadows and agricultural fields. At least part of the cereals must have been imported from distant loess soils, evidenced by the presence of *Orlaya grandiflora*. The mycoflora supports the conclusion that the landscape became deforested during the course of the occupation, as it shows a shift from an assemblage dominated by spores of the tree parasite *Kretzschmaria deusta* to an assemblage dominated by fungi associated with herbaceous plants or dung. The deforestation was probably the result of the high wood demands of the Roman army to build

the castellum and the surrounding *vicus*. Not only was timber needed for building, wood was also used as fuel. Additionally, forest clearance was necessary for the grazing of livestock and to enhance sight around the castellum.

The main crop species that were encountered were spelt wheat (*Triticum spelta*) and barley (*Hordeum vulgare*), which were probably stored for a significant amount of time, as indicated by several coleopteran pest species. The high numbers of glume bases that were encountered suggest that waste was dumped in the residual channel. Faeces were also dumped into the channel as indicated by e.g. high numbers of cereal pollen, intestinal parasite eggs, spores of coprophilous fungi, floral remains of clover, masticated monocot remains, dung beetles, dung fly puparia, and geochemical data. Fruits and seeds of salt-tolerant species were encountered in the core as well. These plants did not grow in the direct vicinity of Fectio, but the fruits and seeds were probably transported to the area in the intestines of horses that had been grazing in coastal meadows. The dumped material contributed to the extremely rapid sedimentation rate in the residual channel and may have caused over-representation of herbaceous pollen.

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Captions

Fig. 1a: Map of the Netherlands showing Fectio and other castella. 1b: Location of the coring site.

Fig. 2: Roman plaster fragment and botanical and zoological macroremains encountered in the sediment core
a: fragment of painted wall plaster (214 cm depth).
b: crust of calciumphosphate with plant remains and mammal hairs.
c: horse hair.
d: human hair.
e: overview of sieved macrofossil sample showing masticated plant fragments.

f: *Triticum spelta*, glume bases.
g: *Triticum spelta*, epidermis glume base.
h and i: *Triticum* sp., bran.
j: *Hordeum vulgare*, rachis internode.
k: *Coriandrum sativum*, fruit.
l: *Papaver somniferum*, seed.
m: *Malus sylvestris*, seed.
n: *Orlaya grandiflora*, fruit.
o: *Orlaya*, pollen in high and low focus.
p: *Triglochin maritima*, fruit
q: *Agrostemma githago*, seed.
r: *Medicago* spec., fruit with seed.
s: *Rhinanthus* spec., seed.
t: *Plantago lanceolata*, seed.
u: *Daucus carota*, fruit.

Fig. 3: Microfossil percentage diagram. Pollen sum taxa in upper part. With simplified lithology (from light to dark: clay, organic and gyttja). Exaggerations 10x.

Fig. 4: Microfossil concentration diagram for selected taxa and total pollen sum taxa. Note that the x-axis is differently scaled for different taxa.

Fig. 5: Botanical macroremains and microfossils from the Fectio core
a: *Trifolium* spec., calyx.
b: *Trifolium* spec., perianth.
c: *Trifolium* spec., perianth with two insect bore holes.
d: *Trifolium* spec., pollen
e: cluster of unripe *Trifolium* pollen.
f: *Bromus*, fruit with insect bore holes.
g: unidentified plant remains from 240 cm depth.
h: details of g.
i: *Chaetomium* spec, fragment of squashed fruitbody with ascospores.
j: Type 593 fungal spores.
k and l: Type 594 fungal spores.
m: overview pollen slide showing many Type 593 fungal spores.
n: Type 595 plant remain.

Fig. 6: Diagram for fruits and seeds from the Fectio core. Taxa assembled in groups according to habitat type. Note that the x-axis is differently scaled for different taxa. Horizontal lines are zone boundaries based on the microfossil record.

Fig. 7: Bryophytes from the Fectio core

Fig. 8: Wood fragments from the Fectio core

Fig. 9 Fossil coleopteran remains encountered at various depths in the Fectio core
a: Aphididae indet.
b: *Erigone* spec., carapax.
c: *Macronychus quadrituberculatus*, elytron.

d: *Esolus pygmaeus*, elytron.
e: *Hygrotus impressopunctatus*, elytron in sediment.
f: *Aphodius lividus*, pronotum.
g: *Sitophilus granarius*, head.
h: *Sitophilus granarius*, elytron.
i: *Oryzaephilus surinamensis*, elytron.
j: *Typhaea stercorea*, elytron.
k: *Palorus ratzeburgii*, mandible.
l: *Pylaris farinalis*, head capsule of larva.
m: *Pediculus humanus*, part of abdomen.

Fig. 10: Partial gas chromatogram of the sterol fraction derived from the sediment at 213 cm.

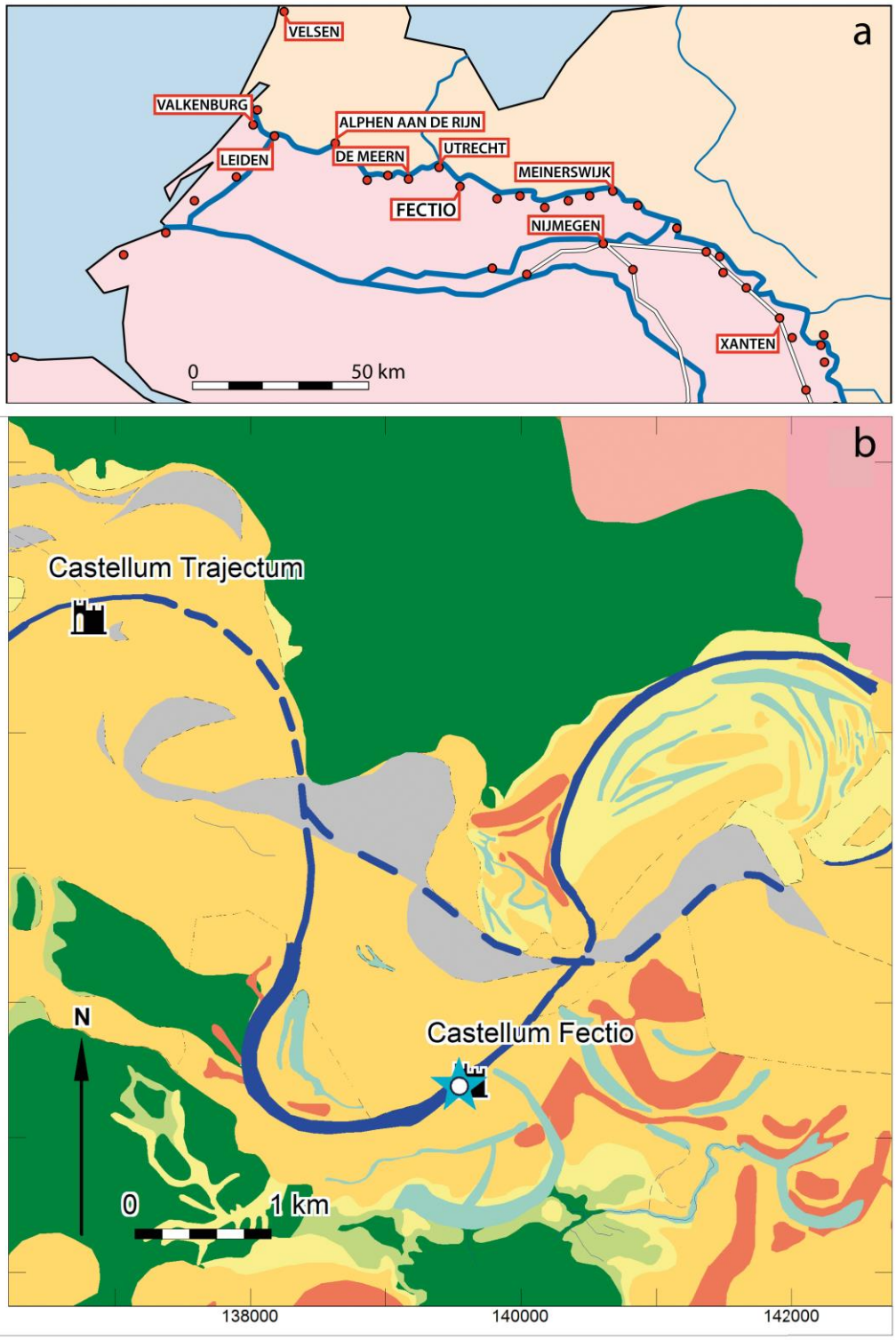
Fig. 11: Map showing the percentages of halophytes (blue) and glycophytes (red) based on sample frequencies for all Roman Period sites in the Netherlands in the Dutch archaeobotanical database RADAR (version nov. 2012). Bright colours are military sites, dull colours are native Roman settlements. Background: palaeogeographical map of the Netherlands 100 AD (Vos et al. 2011, 63).

Table 1: Lithology of the Fectio core.

Table 2 Calibration results of three radiocarbon dates

Electronic Suplementary Material 1: Coleoptera and additional arthropods

Electronic Suplementary Material 2: Cladocera, Bryozoa and Ostracoda



LEGEND

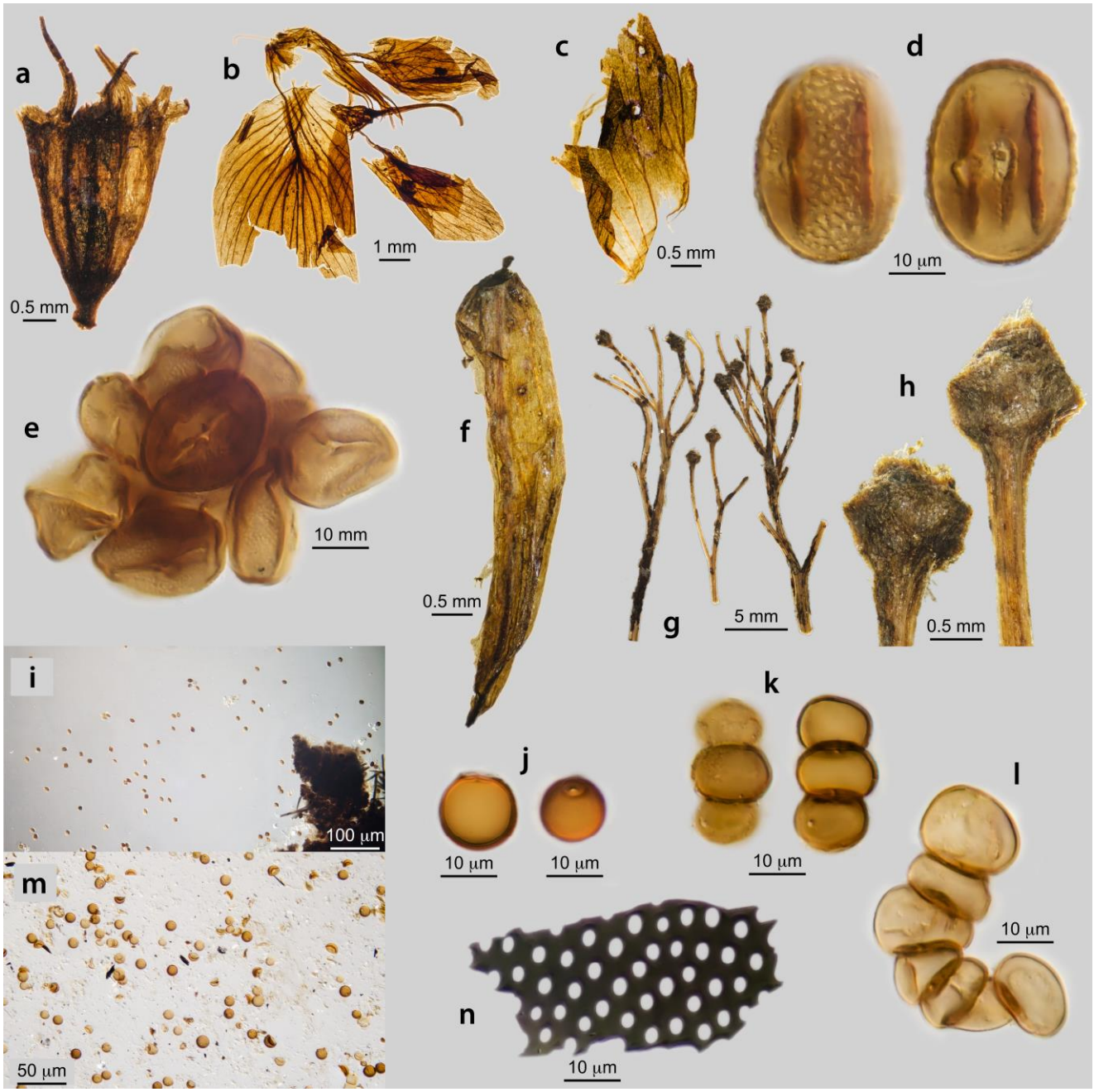
Natural levees

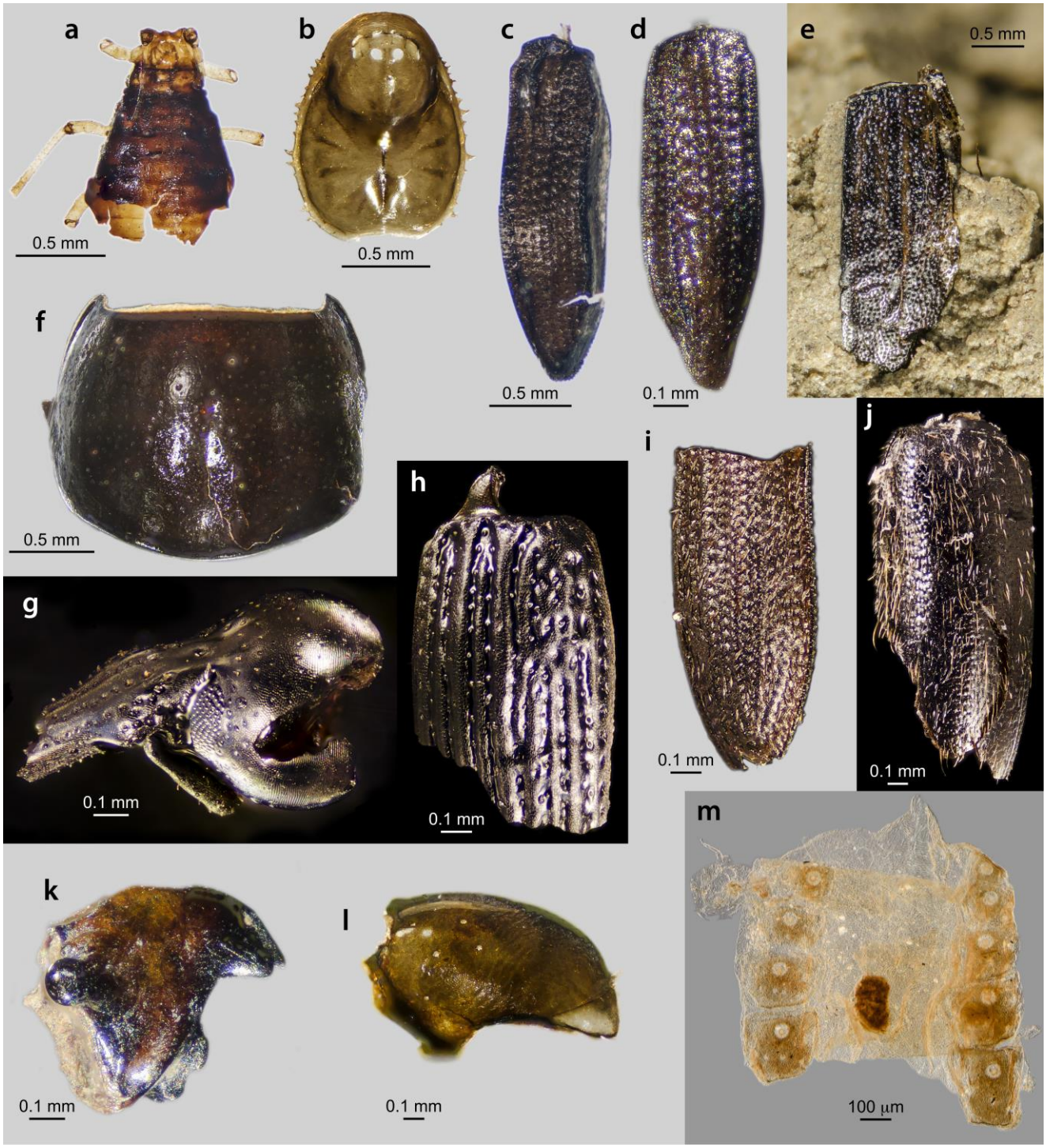
- Very high
- Moderately high
- Low
- Very low, residual gully

Flood plains

- High
- Low

- High Pleistocene grounds
- Post Roman erosion
- Former river channel, uncertain
- Roman Rhine
- Coring site


a
0.5 mm
b
1 mm
c
0.5 mm
d
10 µm
e
10 mm
f
0.5 mm
g
5 mm
h
0.5 mm
i
100 µm
j
10 µm
10 µm
k
10 µm
l
10 µm
m
50 µm
n
10 µm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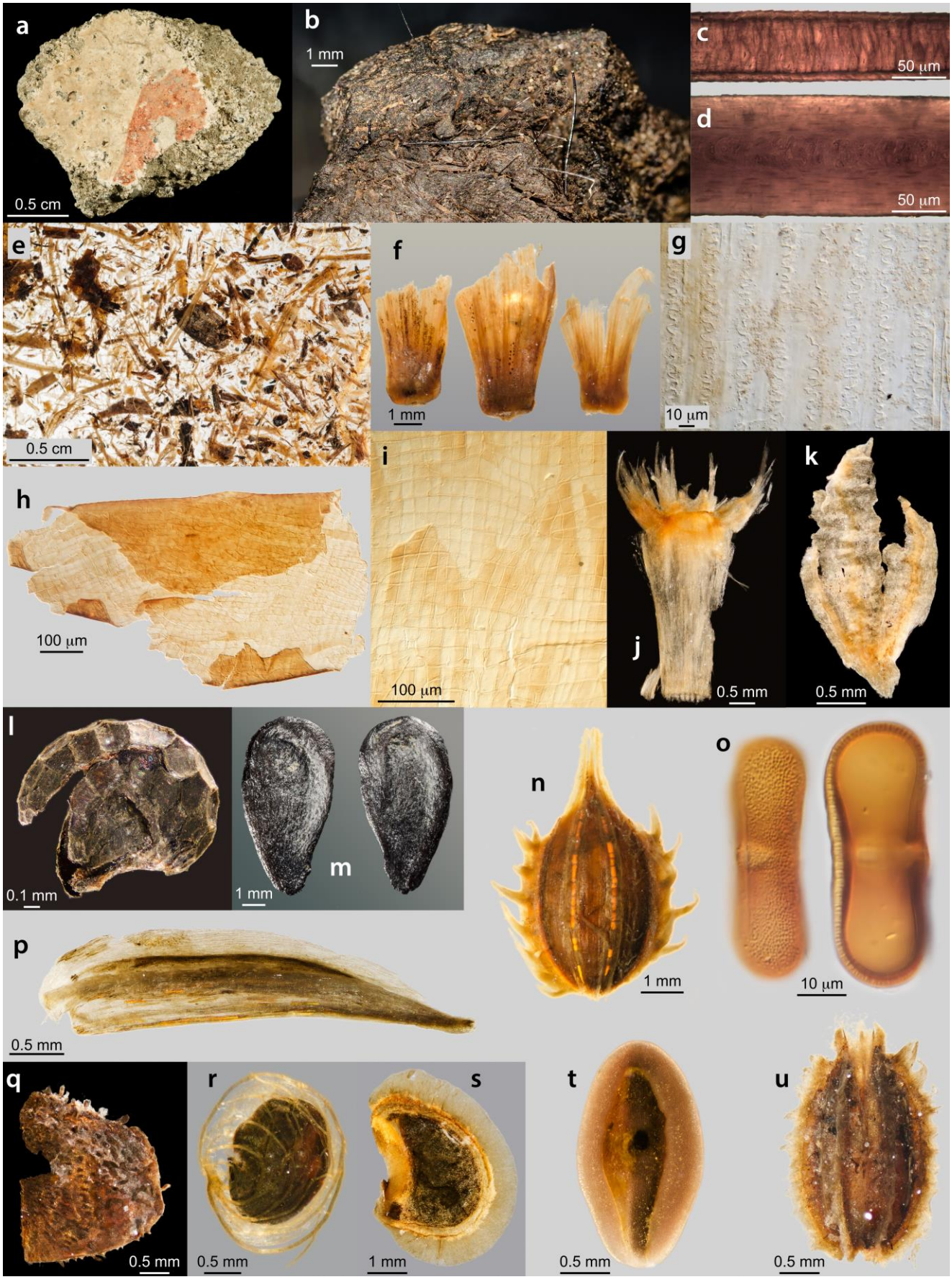
m
100 µm


a
0.5 cm
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i
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j
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k
0.5 mm
l
0.1 mm
m
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p
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r
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s
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t
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u
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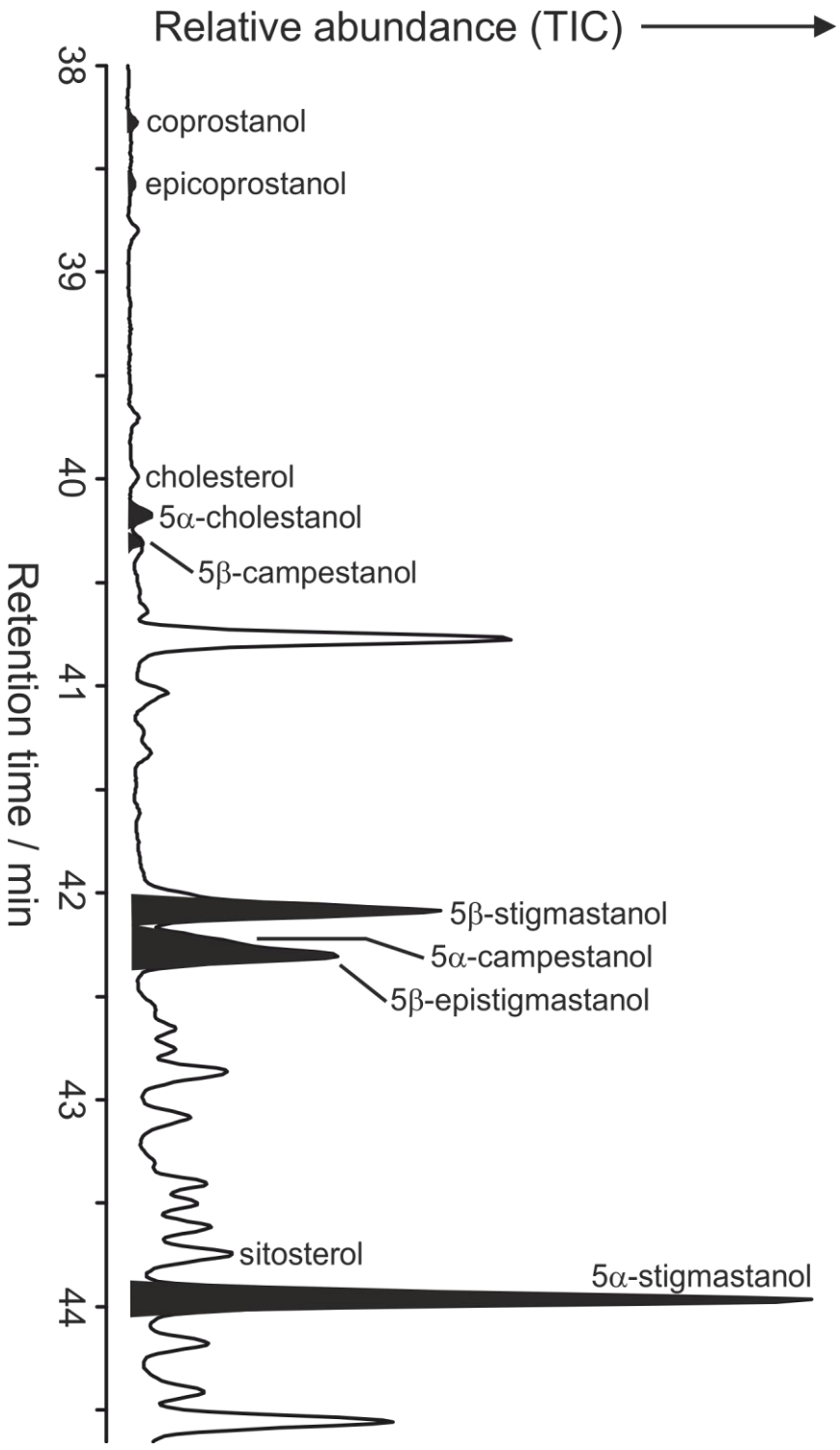
Relative abundance (TIC)
Retention time / min
38
39
40
41
42
43
44
coprostanol
epicoprostanol
cholesterol
5α-cholestanol
5β-campestanol
5β-stigmastanol
5α-campestanol
5β-epistigmastanol
sitosterol
5α-stigmastanol